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Box Creation

Pressure corrected boxes are created by making a box specific to Day 98 111 and scaling it to accommodate the instrument conditions of the time. This method requires tools such as the Ion Trail Equations, Energy Fit Equations, Ion Ranges, and Monroy. An explanation of Monroy can be found in 'Monroy Documentation' while the others are explained in the pages that follow.

The steps to creating a box are as follows:

1. Choose an ion (Z), a mean total incident energy of that ion (<Etot>), and a delta total incident energy for the box to cover from left to right (Δ Etot).

2. Use the <Etot> and Δ Etot to calculate the minimum and maximum total energies for the box:

minEtot = <Etot> - (Δ Etot)/2

maxEtot = <Etot> + (Δ Etot)/2

3. Use the Energy Fit Equations to obtain a minimum and maximum Essd LG ch on Day 98 111 for the box:

4. Use the Ion Trail Equations to obtain a left and right dE LG ch on Day 98 111 for the box:

5. Use the Ion Ranges to obtain the four corners of the box:

6. Use the Monroy to scale this 98 111 box to the instrument conditions of the time:

$$\text{Day Scale} = \frac{\text{Monroy Time (fan, pressure, set)}}{\text{Monroy 98 111 (F2, 24 torr, 106 set)}}$$

dE LL, UL, UR, LR 98 111 * (Day Scale) = dE LL, UL, UR, LR for instrument conditions.

7. Reiterate the process to achieve original <Etot>. Since the scaling of the box is purely vertical in the dE direction, the final total incident energy of the box may be different than the requested <Etot> by more than one ssd channel. If so, create another box based on a higher or lower <Etot> and see if the total energy of this box is close enough to the originally requested <Etot>. The total energy of a box is calculated by taking the average of the total energies of its left and right edges. The total energy of each edge is obtained by the same method as descibed in the Energy Fits section.

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Total Energy Boundaries

Resulting from the boundaries of the Ion Trails and the Energy Fit Equations are boundaries of total incident energies around which a box may be created for each ion.

Boundaries Etot (MeV)	Min	Max
Fe	21	210
Ca	35	199
S	31	193
Si	22	190
Mg	20	187
Ne	13	185

Boundaries Etot (MeV)	Min	Max
O	7	183
N	6	183
C	4	147
He	1.4	16
P+	0.6	5.3

Energy Fit Equations

A necessity for making pressure corrected boxes is a method to go from the total incident energy of an ion to ssd energy in channels. The Energy Fit Equations provide such a tool. These equations are specific to Day 98 111 Fan 2. Points for these equations were created by converting a range of E ssd ch values to total energy in keV for each ion. This process was executed by the following method:

Calculations of Etot (keV) *Essd LG ch* input:

Etot (keV) = dE LG (keV) + Window Eloss (keV) + SSD Dead Layer (keV) + Essd LG (keV) + Pulse Height Defect (keV)

dE LG (keV) = dE LG (ch) * keV:ch Ratio
dE LG (ch) = ion trail equations from *Essd LG (ch)* input
kev:ch Ratio F2, 3 = (Monroy F3 @ 22.2 torr, 107 set (98111)=14.01)/(Monroy at fan,set,pressure)*(16229/1024)*(Pressure/22.2)
for Day 98 111 = (14.01/14.4)*(16229/1024)*(24/22.2) = 16.67

Window Eloss (keV) = 2Windows:Gas Ratio * dE LG (keV)
2win:gas ratio = 15.493*Pressure^(-1.00889)
for Day 98 111 = 15.493*24^(-1.00889) = .628

SSD Dead Layer (keV) = .1 * dE LG (keV)

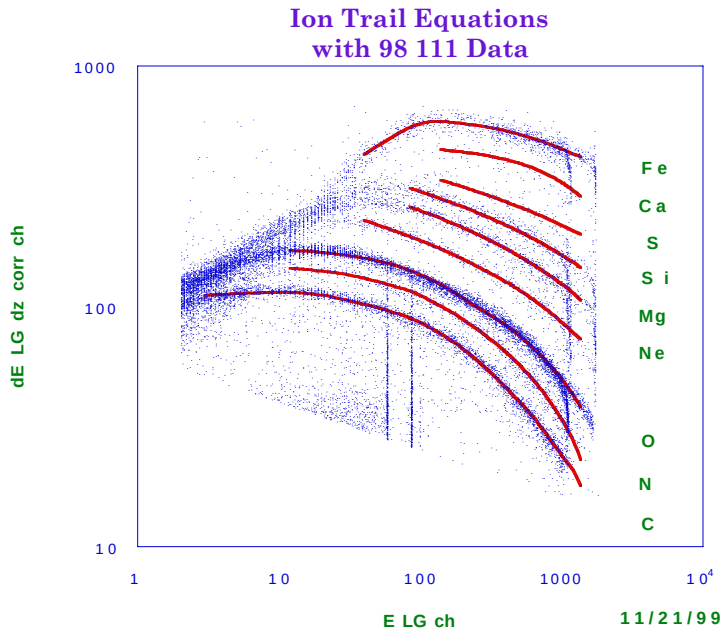
Essd LG (keV) = *Essd LG (ch)* * 133.5

Pulse Height Defect (keV) = DMorris' idl function "phdcorr" which takes Z and Essd (keV)
Z = nuclear charge

This method relies on the Ion Trail Equations, the Monroy, the Monroy-Mark keV:ch ratio and a pulse height defect (PHD) calculation. The PHD used here was obtained by Dan Morris' IDL function PHDCORR as of 12/99. If any of these methods change, the Energy Fit Equations will need to be recrafted. The boundaries of these functions are a result of the boundaries of the Ion Trail Equations.

	Boundaries Etot (keV)		Y=Essd LG X=Etot		Y=M0+M1x+M2x^2+M3x^3...				
	Min	Max	M0	M1	M2	M3	M4	M5	M6
Fe	20328	210906	63.606	-0.00645	3.3399E-07	-4.13E-12	2.7142E-17	-9.048E-23	1.2E-28
Ca	34557	199761	-118.94	0.007418					
S	30152	193427	-83.172	0.007496					
Si	21283	190243	-77.011	0.007762	-9.9424E-10				
Mg	19461	187734	-63.677	0.007801	-1.0575E-09				
Ne	12156	185650	-60.318	0.008582	-1.5039E-08	9.188E-14	-2.003E-19		
O	6595	183883	-40.631	0.008118	-5.2281E-09	1.467E-14			
N	5787	183200	-33.515	0.00808	-5.0186E-09	1.434E-14			
C	3603	182877	-26.39	0.007985	-4.0561E-09				
He	1387	16165	-12.465	.013012	-1.3191E-06	1.5611E-10	-8.7215E-15	1.8386E-19	
P+	569	5386	-1.7581	.0088087	-3.8712E-7	3.5597E-11			

Ion Trail Equations



The Ion Trail Equations were built to mimic Day 98 111 Fan 2 data. Low gain (LG) channel (ch) space was chosen to avoid the complications of energy conversions. The 98 111 data was processed by converting all high gain (HG) channel measurements to LG. E ssd HG values were divided by 20, while HG dE values were converted by adding 42 and then dividing by 15. All dE LG ch were then dZ corrected by multiplying by COS(ATAN(dZ/22.5)). Points for each equation were obtained by histogramming dE for vertical data strips of constant E. Equations were then built to follow the points for each ion. Due to accuracy demands, some ions require two equations.

	Essd LG ch Boundaries	Ion Trail Equations	X= Essd LG ch Y= dE LG ch
Fe	41-136.5	Y=-.024478X^2+5.9409X+228.31	
	136.5-1365	Y=.000058435X^2-.22589X+618.39	
Ca	136-1365	Y=.000018849X^2-.16067X+469.7	
S	136-1365	Y=631.67-138.13logX	
Si	85-1365	Y=573.69-136.76logX	
Mg	85-1365	Y=503.38-126.6logX	
Ne	41-1365	Y=390.09-101.21logX	
O	12-322	Y=176.89-.47454X+.0006548X^2	
	322-1400	Y=306.36-85.485logX	
N	12-80	Y=150.28-.51807X+.00093207X^2	
	80-1365	Y=266.43-77.524logX	
C	5-30	Y=107.17+1.4986X-.086046X^2+.0011558X^3	
	30-1100	Y=115.5-.36435X+.00076553X^2-(9.2493e-7)X^3... ...+(5.6842e-10)X^4-(1.3666e-13)X^5	
He	3-136	Y=42.982-18.253logX	
P+	3-21	Y=12.339X^-.67801	
	21-41	Y=1.6865-.002484X	

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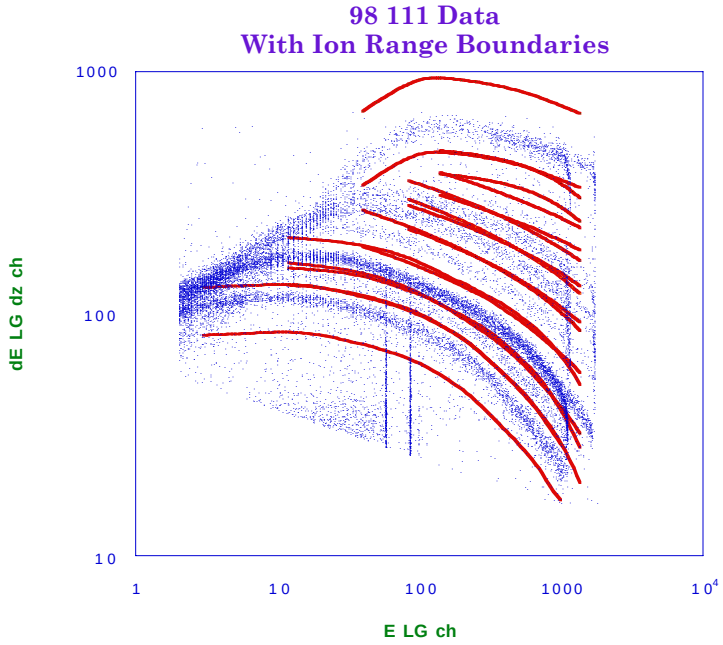
Ion Ranges



The upper and lower box boundaries are determined by the Ion Ranges. These ranges are the ratio of the Ion Trails to their upper and lower box boundaries. The values for these ranges were determined by examining the relationship between the Ion Trails and the 98 111 boxes, as well as viewing the ranges with the data. Some ions require more than one ratio; such trails have an energy dependent ion range. A trail point is multiplied by the appropriate ratio to obtain an upper or lower box boundary.

Ion Ranges:	Energy Range Essd LG	Lower	Energy Range Essd LG	Upper
Fe	all	0.79	all	1.6
Ca	all	0.84	all	1.05
S	all	0.92	all	1.14
Si	all	0.9	all	1.14
Mg	all	0.86	all	1.14
Ne	up to 400	0.83	all	1.17
	400-700	0.81		
	700+	0.79		
O	up to 50	0.9	up to 200	1.2
	50-70	0.89	200-400	1.26
	70-90	0.88	400-700	1.3
	90-400	0.89	700+	1.34
	400-700	0.86		
	700+	0.83		

Ion Ranges:	Energy Range Essd LG	Lower	Energy Range Essd LG	Upper
N	up to 80	0.91	up to 80	1.12
	80-300	0.9	80-200	1.09
	300-400	0.88	200-300	1.13
	400+	0.86	300-600	1.16
			600+	1.19
C	up to 300	0.73	up to 150	0.15
	300+	0.71	150-500	0.2
		0.77	500+	0.23
He	all	0.45	all	2.1
P+	all	constant of 1	all	3.8

Pulse Height Defect Functions

The most accurate way to calculate PHD is to use an iterative process. This is inconvenient, however, when working in an Excel environment or when using a hand-held calculator. Consequently, a set of functions has been crafted for such purposes. The following equations were obtained by inputting a range of Essd (keV) values into Dan Morris' PHDCORR IDL function and fitting them to their output PHD (keV).

Pulse Height Defect Fits for Each Species:

	Fits Created Around this Essd(keV) Range:	Y=PHD(keV) X=Essd(keV)
Fe	5340-182228	Y=30.808*X^.51796
Ca	18690-182228	Y=21.407*X^.50127
S	18690-182228	Y=14.965*X^.48717
Si	11348-182228	Y=11.399*X^.48026
Mg	11348-182228	Y=7.6039*X^.47631
Ne	5340-182228	Y=4.3689*X^.47170
O	1602-182228	Y=1.9031*X^.46781
N	1602-182228	Y=1.0524*X^.46634
C	401-182228	Y=.49374*X^.46265

When applied to the above range of Essd (keV) values, these fits result in PHD (keV) which deviate from the iterative values by less than 1% with the exception of iron, which may deviate by no more than 2.6%.

Another useful equation for evaluating PHD is the generalized PHD fit. This equation is applicable to all ions by depending on both Essd (keV) and nuclear charge (Z). These values deviate by no more than 1.4% for most ions and 2.6% for iron. Some accuracy is lost in the O, N, and C ions, whose deviations are less than 4%, 7%, and 15% respectively.

Nuclear Charge (Z):	
Fe	26
Ca	20
S	16
Si	14
Mg	12
Ne	10
O	8
N	7
C	6
He	2
P+	1

Generalized Pulse Height Defect Fit for any Z:

Z Boundaries: 6-26
Essd (keV) Boundaries: Same as above for each species

$$PHD(keV) = A * (Essd(keV))^B$$

$$A = 12.331-4.8447(Z)+.61385(Z^2)-.024277(Z^3)+.00034175(Z^4)$$

$$B = .42436+.011571(Z)-.0011797(Z^2)+(6.0031E-5)(Z^3)-(1.0174E-6)(Z^4)$$

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Software

Box Maker:

An IDL program which allows the user to create a set of boxes while viewing them with the data. A SEPICA or BIN2D data listing is graphed in LG channel space. The user chooses an ion, mean energy and delta energy for a box. The program creates such a box according to the aforementioned method and plots it over the data. The user may keep this box or alter it manually. Additional boxes are created and plotted with other boxes. A '.bins' box file may be created for the set of boxes in various energy or channel spaces. To use Box Maker, go to the Ace Software directory and at the IDL prompt, type :

```
.r conversions
.r boxfuncs
boxmaker
```

More about this program is contained at the beginning of the file 'boxmaker.pro' in the Ace Software directory. A read-only copy of this program is located in /home/emorse/boxmaker. A SEPICA listing of Day 98 111 heavy ions is located in the file /home/popecki/aceda/98111boxes/uppertraces.dat. This is a good set of data for someone who wants to test out the program. Information for this file: 14 columns, 19050 rows, fan 2, pressure 24, set 106.

Box Plot:

An IDL program which will read in a '.bins' box file, read in a SEPICA or BIN2D data listing, and plot them both in LG channel space. To use Box Plot, go to the Ace Software directory and at the IDL prompt, type: boxplot

More about this program is contained at the beginning of the file 'boxplot.pro' in the Ace Software directory. A read-only copy of this program is located in /home/emorse/programs.

RT Format:

An IDL program which will read in a '.rt' phaflux output file and will convert the data to an easy-to-graph format. Such a file may be read into kaleidagraph or excel and plotted instantly! To use RT Format, go to the Ace Software directory and at the IDL prompt, type: rtformat

More about this program is contained at the beginning of the file 'rtformat.pro' in the Ace Software directory. A read-only copy of this program is located in /home/emorse/programs/formats.

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IDL Functions

Within the file 'boxfuncs.pro' in the Ace Software directory are numerous functions for all of the tools necessary to create pressure corrected boxes. More information about each functions is located within the file 'boxfuncs.pro'.

IONTRAIL
Input: Z, Essd (LG ch)
Output: dE (LG dz corrected ch)

MONROY
Input: fan, pressure, anode voltage set
Output: dE (LG dz corrected ch) of calibration alphas (F2,3) or source alphas (F4)

ENERGYFIT
Input: Z, total energy (MeV)
Output: E ssd (LG ch)

WINDOW
Input: pressure
Output: 2windows:gas energy loss ratio

KEVCHRATIO
Input: fan, pressure, anode voltage set
Output: keV:channel dE ratio

IONRANGE
Input: Z, Essd (LG ch), /UPPER, /LOWER
Output: either the upper or lower ion range ratio

BOX
Input: Mean E total (MeV), delta E total (MeV), Z, fan, pressure, set
Output: array of box boundaries in LG ch space (doesn't calculate box iteratively)

ETOTAL
Input: Essd (LG ch), dE (LG dz corr ch), Z, fan, pressure, set
Output: total incident energy (keV)

BOXETOT
Input: min Essd (LG ch) for box, max Essd (LG ch) for box, Z, fan, pressure, set
Output: total incident energy for the box

INPUTCHECK
Input: mean Etot (MeV), delta Etot (MeV), Z
Output: 1 if inputs are within boundaries, 0 if inputs are out of boundaries

REBOX
Input: Mean E total (MeV), delta E total (MeV), Z, fan, pressure, set
Output: array of box boundaries in LG ch space (calculates box iteratively)

MAKEBOXFILE
Input: array of box boundaries, # of boxes, array of box names, file name, fan, pressure, set, /LGCH, /OLD, /NEW (specifies channel or keV space)
Output: '.bins' file which may be read by Phaflux

Excel Formulas

The Excel version of Box Maker exists in the folder 'Box Folder' on the Power PC 113 Desktop in zone SSG. Within the Excel spreadsheet 'Box Maker' are worksheets which contain the data used for this document. All equations mentioned in this document have been made into Excel cell formulas. These may be found on each worksheet and are highlighted with red titles and have black borders. These are very useful for anyone who works with Excel as they eliminate the need to type in long equations!

References

For additional information or data regarding any of the graphs seen in this document, contact Mark Popecki (mark.popecki@unh.edu).